Ten years of war: A characterization of craniomaxillofacial injuries incurred during operations Enduring Freedom and Iraqi Freedom

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BACKGROUND:	Improved armor and battlefield medicine have led to better survival in the wars in Iraq and Afghanistan than any previous ones. Increased frequency and severity of craniomaxillofacial injuries have been proposed. A comprehensive characterization of the injury pattern sustained during this 10-year period to the craniomaxillofacial region is needed to improve our understanding of these unique injuries, to optimize the treatment for these patients, and to potentially direct strategic development of protective equipment in the future.
METHODS:	The Joint Theater Trauma Registry was queried from October 19, 2001, to March 27, 2011, covering operations Enduring Freedom and Iraqi Freedom for battle injuries to the craniomaxillofacial region, including patient demographics and mechanism of injury. Injuries were classified according to type (wounds, fractures, burns, vascular injuries, and nerve injuries) using DRG International Classification of Diseases 9th Rev. diagnosis codes.
RESULTS:	In this 10-year period, craniomaxillofacial battle injuries to the head and neck were found in 42.2% of patients evacuated out of theater. There is a high preponderance of multiple wounds and open fractures in this region. The primary mechanism of injury involved explosive devices, followed by ballistic trauma.
CONCLUSION:	Modern combat, characterized by blast injuries, results in higher than previously reported incidence of injury to the craniomaxillofacial region. (*J Trauma Acute Care Surg*. 2012;73: S453 S458. Copyright © 2012 by Lippincott Williams & Wilkins)
LEVEL OF EVIDENCE:	Epidemiologic study, level IV.
KEY WORDS:	Craniomaxillofacial injury; blast injury; explosive devices; ballistic trauma.

The craniomaxillofacial (CMF) region is not well protected by contemporary armor technologies and is thus vulnerable on the battlefield. This has become evident in the ongoing US military operations in Iraq and Afghanistan as torso armor has led to improved survival, as demonstrated by multiple epidemiologic studies.[1,2]

Head and neck injuries have historically constituted 16% to 21% of battle injuries (BIs).[3–5] Much of our knowledge of military CMF trauma, however, has been published as case series, with a generally short time interval.[6–14] Brennan[6] reported his 5-month experience as the first deployed otolaryngology team and performed 257 procedures among 159 patients. His most common operation was laceration repair of the face followed by tracheostomy and exploration for facial bleeding. Wade et al.[7] reported a 7-month review of the Navy-Marine Corps Combat Trauma Registry, in which head and neck injuries accounted for 52% of battle-related injuries. Reasons for the short durations for most studies may be related to the length of deployment, which is generally in 6-month intervals and governs the authors' experiences. The past 10 years represent the longest war since the Vietnam War, and a cumulative analysis incorporating all the data from the past 10 years would be valuable.

Our group has previously reviewed the 6-year experience on CMF BIs from 2001 to 2007 and found that its incidence increased as compared with that of previous wars.[15] We had reported that the ongoing US wars in Iraq and Afghanistan had a 26% to 29% rate of CMF BIs during those 6 years, with all other BIs remaining constant or declining.[1,15] The improvement in body armor and battlefield medicine and increased encounters with explosive devices used by insurgent forces were cited as potential culprits. Limitations of this study, however, include a limited study period and a narrower definition of CMF injuries.

The objective of the present study was provide a comprehensive overview of CMF BI, with an expanded definition to include fractures, soft tissue injuries, nerve injuries, vessel injuries, and burns to the head and neck, collected during the entire 10-year period to give a more representative view of CMF battle trauma.

PATIENTS AND METHODS

This study was conducted under a protocol reviewed and approved by the US Army Institute of Surgical Research and

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This study was conducted under a protocol reviewed and approved by the US Army Medical Research and Materiel Command Institutional Review Board and in accordance with the approved protocol.

The opinions or assertions contained herein are the private views of the authors are not to be construed as official or as reflecting the views of the Department of the Army, Air Force, or the Department of Defense.

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TABLE 1. Total Number of Battle-Injured Patients and Those With ICD-9 Codes for CMF Injuries at Various Echelons of Care

Echelon	Total Injured*	CMF ICD-9Dx
III	15,209	5,094 (33.5%)
IV	**9,530**	**4,020 (42.2%)**
V	8,637	3,242 (37.5%)

*Figures from the Department of Defense. Boldface indicates patients evacuated out of theater as defined by transferred to Echelon IV and above.

the US Army Medical Research and Materiel Command Institutional Review Board.

The Joint Theater Trauma Registry (JTTR) is a registry of all US service members injured in Operation Iraqi Freedom/Enduring Freedom (OIF/OEF) admitted to a military treatment facility (MTF) at Level III or higher, spanning all military services, including both BIs and non-BIs. The JTTR was created to include entries starting from the beginning of OEF, October 2001, and has been continually updated, based on the Abbreviated Injury Score (AIS) and DRG International Classification of Diseases—9th Rev (ICD-9) diagnosis codes and information abstracted from the patients' medical records, expert clinical inference, and process improvement data.

The JTTR was queried for all US service members with CMF BI evacuated out of theater through the use of ICD-9 diagnosis codes. The ICD-9 diagnosis codes used include the following: 374.02, 374.04, 374.12, 374.14, 374.2 to 374.47, 376.47, 379.8, 380.32, 470, 523.9, 525.11, 526.89, 527.8, 528.5, 528.9, 529.3, 738, 738.1, 802 to 802.9, 804, 830, 830.1, 870.3, 870.4, 870.8, 870.9, 872, 873 to 873.9, 900 to 900.9, 905, 906, 907.1, 910, 920, 921, 925.1, 940, 940.1, 941 to 941.26, 947, 950 to 950.3, 950.9, 951 to 951.9, 959, 959.09. CMF injuries include fractures, soft tissue injuries, nerve injuries, vessel injuries, and burns to the head and neck. The total number of injured service members during the study period and the patients transferred to escalating echelons of care were also obtained from the JTTR.

Repeat ICD-9 codes assigned to a given patient, owing to the multiple levels of care, were removed from the query, as were combatants classified as killed in action or returned to duty (discharged from medical care within 72 hours after admission). Isolated intracranial injuries, corneal abrasions, tympanic membrane ruptures, and nonbattle-related injuries were also excluded.

The study database was maintained under data encryption in Access (Microsoft Corp., Redmond, WA). This is a descriptive study, and no statistical comparisons were performed.

RESULTS

Denominator

The Department of Defense reported that 43,822 total servicemen and women were injured during the 10-year period from 2001 to 2011.[16] Based on data obtained from the JTTR, among BIs, 15,209 required patient evacuation at least to a Level III (combat support hospital or higher) MTF for further treatment; 9,530 patients were evacuated out of theater to a Level IV (Landstuhl, Germany) MTF; and 8,637 patients were evacuated to a Level V MTF in the continental United States (Table 1). The study denominator was chosen to be the number of BI service members evacuated to an Echelon IV MTF. These were patients whose injuries were serious enough to require evacuation out of theater, rendering them incapable of returning to duty.

CMF Injuries

Based on our query of the JTTR using the ICD-9 diagnosis codes, 4,020 patients (42.2%) who were evacuated out of theater (i.e., to a Level IV facility) were identified as having CMF BIs such as fractures; dislocations; soft-tissue, nerve, and vessel injuries; and burns (Table 1). Sixteen of these patients were injured twice to the CMF region in this study period but during separate deployments. For the purpose of analysis, those patients were counted twice, making the total evacuated CMF BI 4,036. CMF BIs were found in 5,094 (33.5%) and 3,242 (37.5%) among those presenting to Level III and V facilities, respectively.

Demographics

The demographics of patients evacuated out of theater with CMF BIs are listed in Table 2 along with the branch of service, military operation, survival, and Injury Severity Score (ISS). Most CMF BIs were sustained by men compared with women (98.2% vs. 1.8%). The average age per patient was 26 years. The incidence of CMF BI by branch of service was Army at 75%, Marines at 21%, Navy at 2%, and Air Force at 1.5%.

Mechanism of Injury

The predominant mechanism of CMF BIs was explosives (including improvised explosive devices and rocket-propelled grenades) (88%). Ballistics came in at a distant second (7%), followed by motor vehicle collisions (2%) (Fig. 1).

TABLE 2. Demographics of CMF Battle-Injured Patients Who Were Evacuated out of Theater

	CMF Injured	
Demographic	**n**	**Percentage**
Average age	25.76	
Sex		
Male	3,965	98.2
Female	71	1.8
Military operation		
Iraqi Freedom	3,052	75.6
Enduring Freedom	984	24.4
Military branch		
Air Force	62	1.5
Army	3,000	75.3
Navy	84	2.0
Marines	890	21.3
Survival	3,975	98.5
ISS	14.81	
Total	4,036*	

*A total of 4,036 CMF BI patients was used for all subsequent analyses because 16 of the 4,020 patients identified based on our query of the JTTR were injured twice to the CMF region in this study period but during separate deployments.

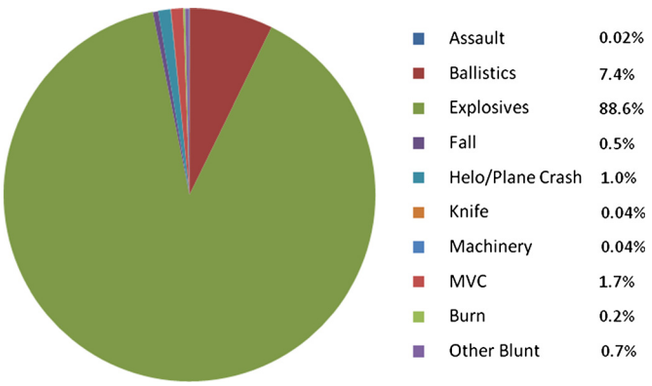

Figure 1. Mechanism of injury among CMF battle injured and evacuated out of theater.

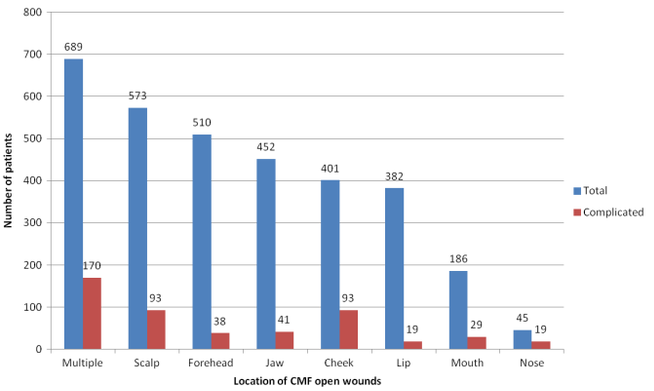

Figure 2. Distribution of open wounds among CMF battle injured and evacuated out of theater.

Nature of Injury Based on ICD-9 Diagnosis Codes

Based on ICD-9 diagnosis codes, CMF BIs were noted in 4,036 patients and were classified into several broad categories. Open wounds represented the largest proportion of BIs (65%), followed by fractures (44%), burns (10%), vessels (6%), and nerves (6%) (Table 3).

Open Wounds

Given that the skin is the organ with the largest surface area and serves as our outer protective barrier, it is also the most susceptible to the high-energy kinetics imparted by explosive devices. CMF open wounds were present in 2,630 battle-injured patients (65%) evacuated out of theater. The locations of these wounds are expectedly located on multiple areas, with most common involvement being the scalp and forehead, jaw, cheek, and lip, in decreasing order of frequency (Fig. 2). *Multiple* refers to wounds not isolated to one anatomic location. The wounds can be further subclassified as complicated, defined by delayed healing, delayed treatment, foreign body retention, and infection. Burns are a unique category of wounds and are described separately below.

Fractures

The CMF skeleton can generally be divided into thirds (upper, middle, and lower), corresponding to the frontal skull, midface (malar/maxillary, orbital, nasal), and mandible. In our study, however, the frontal skull is not uniquely specified and is categorized together with others, which also includes multiple and miscellaneous fracture patterns. CMF fractures were present in 1,779 battle-injured patients (44%) evacuated out of theater. Midfacial bones (combining malar/maxillary, nasal, and orbital) sustained the most injury, relative to the mandible (Fig. 3). There was also a high preponderance of open fractures (75%), as would be expected by the high incidence of penetrating blast trauma in BI patients.

TABLE 3. Injury Distribution Among CMF Patients Injured in Battle and Evacuated out of Theater

Distribution of Injuries	CMF Injured	
	n	Percentage
Open wounds	2,630	65.2
Fractures	1,779	44.1
Burns	419	10.3
Vessels	250	6.19
Nerves	244	6.05
Total	4,036	

Burns

Concomitant facial burns were present in 10% of patients with CMF BIs or 419 patients (Table 3). The stratification of the various locations of burns is further described in Supplemental Digital Content 1 (http://links.lww.com/TA/A203). As expected, most facial burns are classified as multiple, occurring in more than one anatomic location (24%). The neck (18%), periocular region (16%), and ears (15%) are the most common isolated regions involved.

Nerve Injuries

CMF nerve injuries were present in 244 BI patients (6%) evacuated out of theater. Among the total CMF nerve injuries, the facial nerve (34%) was the most commonly injured, followed by the acoustic (30%) and optic nerves (15%) (http://links.lww.com/TA/A204).

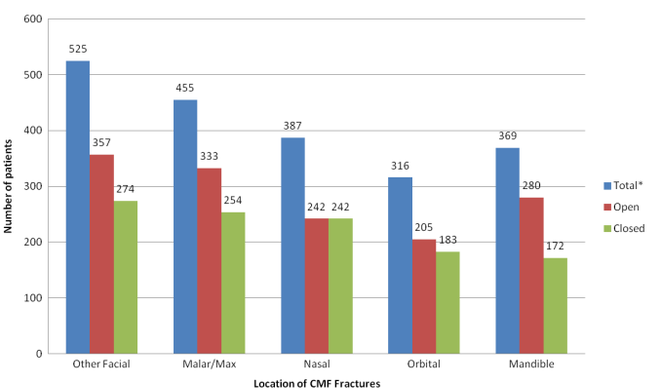

Figure 3. Distribution of fractures among CMF battle injured and evacuated out of theater.

Vessel Injuries

CMF vascular injuries were present in 250 battle-injured patients (6%) evacuated out of theater. Although vessel injuries are among the least frequent injury type to the CMF region among these broad categories, they are almost always urgent problems and can take up tremendous resources and require proper preparation.[17] Although most vessels are unnamed (46%), named vessel injuries (54%) occurred to the central arteries and veins (common, external, and internal carotid arteries as well as the internal and external jugular veins) that can result in massive hemorrhage (http://links.lww.com/TA/A205).

DISCUSSION

The present study represents a comprehensive analysis of CMF BIs sustained by evacuated US service members in OEF and OIF during a 10-year period; it is one of the largest cohorts of CMF BIs since the Vietnam War (1961–1975). While it seems, at first glance, straightforward to determine the exact number of patients who sustained CMF BI, one must be careful in considering the methodology used in published studies so that similar numbers can be used for comparison. Indeed, the number and percentage reported for CMF BI in the literature varies widely. A review by Wade et al.[7] of the Navy-Marine Combat Trauma Registry revealed the incidence to be 52%, whereas Breeze et al.[10] of the Royal Centre for Defence Medicine reported its incidence as low as 14%.

Differences between studies are likely caused by methodology in how the data are captured, processed, and analyzed; these factors need to be considered when making comparisons. First, the group used to define the denominator has to be reflective of and encompass the subset being studied.

Second, the definition of CMF BI can vary between studies, making it difficult to make comparisons. Several studies cite only wounds in their consideration of CMF BIs and exclude fractures and burns, which may result in a seemingly lower incidence.[1,18] In contrast, inclusion of isolated corneal abrasions, tympanic membrane ruptures, or intracranial injuries and concussions can lead to an overestimation of the true incidence. Furthermore, descriptive studies of injuries limited to a single region might either overrepresent or underrepresent the true incidence of CMF BI. Depending on the goal of the study, the definition of CMF BI will be different.

Third, when analyzing combat-related studies, the readers might also consider whether data were limited by the echelons of care where services were rendered. Level I and II MTFs are battalion aid stations and surgical company stations, respectively, used for triage and definitive treatment of minor injuries. Level III MTFs are combat support hospitals, and Level IV MTFs are regional referral hospitals such as Landstuhl Regional Medical Center in Germany. Finally, Level V MTFs are facilities in the continental United States where definitive care of most serious injuries is rendered. The denominator chosen for this study is battle-injured service members evacuated to an Echelon IV MTF or higher. We limited our subset to CMF BIs requiring evacuation out of theater because these patients have more serious injuries that render a soldier unable to return to duty in 14 days.

Last, most studies have a limited period of evaluation, approximately 6 months, which does not capture the data during the duration of the war and therefore only represents a small "snapshot" of what is occurring. For example, several articles chronicle 6-month intervals in 2004, a period known to have the highest number of casualties,[7] in which they found the incidence of CMF BIs to be 52%; however, the cumulative incidence is likely lower when averaged during a longer period.

Considering all these factors, we have defined CMF injuries to include fractures, soft tissue injuries, nerve injuries, vessel injuries, and burns in battle-injured patients evacuated out of theater during the 10 years from 2001 to 2011. This study represents one of the longest series in the literature and representative of the 10 years of war, OIF/OEF.

This study did not specifically address intracranial injuries or isolated tympanic membrane ruptures and corneal abrasions. Although these injuries are exceedingly common and deserve further study, they were excluded from our analysis. The association of intracranial injury with maxillofacial injuries, while inferable, has not been clearly studied and deserves further analysis as well.

Although the exact percentage of CMF BIs can be debatable, there is no doubt that there has been a rise in its incidence in this war. Despite improvements in body armor, battlefield medicine, tactically placed surgical units, and rapid evacuation, we have noted a rise in CMF BIs from our study as compared with previous wars (Vietnam, 16%[3]; Korea, 21%[4]; World War II, 21%[5]). Alternatively, the numbers of CMF BIs may also have risen as soldiers who would have been killed in action in previous wars are now surviving at increased rates, adding to the incidence of CMF BIs. Better documentation and reporting practices in the field are also likely to be a contributing factor to this increase. Whatever the reasons for the rise, there is a need to develop new agents, therapeutics, and surgical strategies that can adequately address the myriad of long-term deformities that often result from CMF BIs.

This study provides both an overview and a detailed analysis of the type of injuries sustained to the CMF region in the battlefield. It is important in understanding the limitations of our current treatment strategies in addressing injuries to this region; in addition, it provides some perspective to future analyses that should be performed. When using these data, one must be cognizant that the percentage of incidence of each injury type should not be construed as the order of importance. For example, while soft tissue wounds represent the largest proportion of injuries (60%), they do not necessarily correspond to the same degree of resource use or disability. Indeed, while nerve injuries, vessel injuries, and—in particular—burns take up a smaller portion of the pie, they are more treatment intensive and may require longer hospital stays, more operative resources, subspecialty consultations, and long-term disability costs. This is a limitation of the study. The characterization is based on ICD-9 diagnosis codes, and conclusion cannot be drawn about the treatment of the patients or outcomes from the injury.

Our analysis of the mechanism of injury resulting in CMF BIs led to similar conclusions as those studies of other body regions.[1,2,19] For example, most injuries to the CMF area, similar to the extremities, are a result of explosive devices.

Most patients have wounds. These wounds are typically contaminated with metallic fragments, rocks, dirt, and other organic material.[20] Repair of these wounds likely requires multiple stages, including debridements followed by coverage. Subspecialty consultations are important in achieving the best outcome. Many late correction and secondary revisions are frequently needed, although these data will require a more detailed analysis of each injury.

Fractures of the CMF skeleton are likely a result of penetrating trauma from an explosion. Midfacial bones sustained the most injury, followed by the mandible in this series. Protective armor such as helmets might afford protection for the skull, but the middle third of the head is more difficult to protect as any barrier may decrease the senses critical in the battlefield. Several published reports have reported mandible fractures as the most common, but that is often because the facial fractures were broken up into maxilla, nasal, zygoma, and orbit.[15,21] When these numbers are combined, facial fractures predominate.

Little is known about nerve injuries as a result of BI, and even less is published on the injuries to cranial nerves. Fortunately, the incidence of nerve injuries is relatively small as the resulting deficits can be devastating. The incidence of peripheral nerve injuries to the extremities have been reported to be 1.5% to 2.8%.[22] This is lower than our reported incidence of 6% to the cranial nerves. Most of these injuries sustained are to the 7th (facial), 8th (acoustic), and 2nd (optic) nerves. Because the incidence of hearing loss after blast is high, it is likely that some of these nerve injuries were overreported because of symptoms of hearing loss or blurriness and not necessarily from known anatomic injuries to the nerves.

The rate of vascular injury in this war is reported to be approximately 12%.[23] The exact incidence depended on operational tempo, but this is approximately five times the incidence reported than in previous wars. We found the incidence of vascular injuries among CMF BIs to be 6%. While emergency tourniquets can be used to prevent exsanguinations from extremity vascular injuries,[24] severe injuries to the central vessels of the head and neck are not easily compressible and are generally fatal and might account for the lower incidence observed in this study.

Burns have historically been and continue to be an important contributor to BIs. The incidence among those evacuated from OIF and OEF was approximately 5%.[1] However, these were disproportionately distributed toward body areas not protected by clothing or equipment. Thus, hands and face involvement was present in 80% and 77% of all burn casualties, respectively.[19] It is not surprising that in this study of CMF injuries, burn was seen in 10% of those injured. Because thermal injuries result in burn scars that require long-term follow-up, specialized care hospitals are needed to provide for their acute resuscitation, coverage, rehabilitation, and reconstruction. Unlike wounds, fractures, and vascular injuries, the care of the burn patients extends far beyond their acute hospitalization and can result in significant long-term disability. Facial burn continues to be an area of focus for reconstructive surgeons and is a broad subject for multidisciplinary investigations.

CONCLUSION

Modern combat, characterized by blasts, results in a unique pattern of CMF injuries. They are dominated by open, complicated wounds and fractures as well as burns to multiple anatomic subunits. An overview of the injuries seen in the modern battlefield, as reported here, may direct future studies that can deepen our understanding of each individual injury type, potentially direct strategic development of protective equipment, and aid in the development of novel agents, therapeutics, and surgical strategies needed to treat or prevent any long-term functional and aesthetic deformities.

AUTHORSHIP

Each author contributed substantially to the article as follows. R.K.C. contributed in the literature search, study design, data collection, data analysis, data interpretation, writing, and figures. A.S. .J. contributed in the data interpretation, writing, and figures. A.J.V. contributed in the literature search, study design, data collection, and data analysis. J.W. contributed in the literature search, data collection, and figures. R.G.H. contributed in the literature search, study design, data interpretation, and writing.

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DISCLOSURE

The authors declare no conflicts of interest.

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